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RESULTS AND ANALYSES OF AEROJET-GENERAL UTILITY VAN CERTIFICATION PROGRAM

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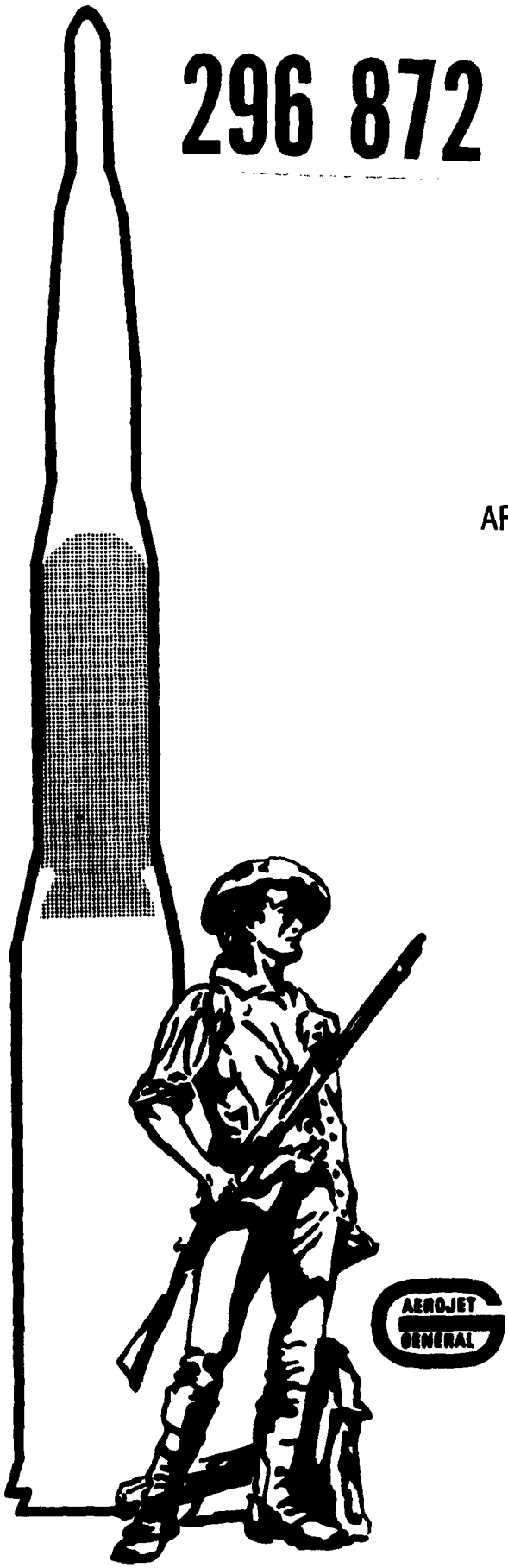

AEROJET-GENERAL CORPORATION
SOLID ROCKET PLANT • SACRAMENTO, CALIFORNIA
A SUBSIDIARY OF THE GENERAL TIRE & RUBBER COMPANY

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Prepared for

HQ., AIR FORCE BALLISTIC SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND, USAF
AIR FORCE UNIT POST OFFICE
Los Angeles 45, California

Attn: Tech Data Center

Approved by:

C. C. Conway, Manager
Minuteman Program

AEROJET GENERAL

SOLID ROCKET PLANT SACRAMENTO, CALIFORNIA

A SUBSIDIARY OF THE GENERAL TIRE & RUBBER COMPANY

PREFACE

Acknowledgment is made to the following persons for the preparation of this report: K. H. Staacke, Development Engineer; A. L. Karnesky, Manager, Dynamics Department; W. D. Hulse, Test Engineer, Mechanical Environment group; Max Halebsky, Minuteman Environmental Program; and D. P. Campbell, Technical Editor.

ABSTRACT

RESULTS AND ANALYSES OF AEROJET-GENERAL UTILITY VAN CERTIFICATION PROGRAM

The Aerojet-General Utility van has successfully completed certification-test requirements to qualify as a transport vehicle for Minuteman second-stage operational motors. The Aerojet Utility van, while transporting live second-stage motors supported in an Aerojet universal harness, was subjected to a series of plank-strip-course and rough-road condition tests to produce sinusoidal inputs to accelerometer locations on the universal harness and motor. A comparative analysis of the acceleration-response data recorded during these tests with data recorded during the tests of four other van-harness combinations is presented.

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FIGURE LIST

I. INTRODUCTION

Tests of five transport van-harness combinations with live Minuteman second-stage motors have been conducted at Aerojet-General, Sacramento. The performance of the Aerojet Utility van and the Aerojet harness has been evaluated and compared with the performances of other van-and-harness combinations. The characteristics of response of the second-stage motors to vibrations loads imposed during the tests have been compared and analyzed.

II. SUMMARY

Under normal transportation conditions, Minuteman second-stage motors will not be subjected to acceleration loads in excess of the 3-g limit load, which the motor is designed to withstand.

The Aerojet Utility van, in combination with either the Aerojet harness or The Boeing Co. (TBC) operational harness, is capable of transporting operational Minuteman second-stage motors without exceeding the 3-g limit under normal transportation conditions.

III. TECHNICAL DISCUSSION

A. TEST UNITS

1. Van-Harness Combinations

The following van-harness combinations were subjected to the plank-strip course and to the rough-road tests:

III, A, Test Units (cont.)

Combination	Van	Harness
a	Aerojet Utility van	TBC operational harness
b	Aerojet Utility van	TBC operational harness (with Autonetics NCU installed on motor)
c	Aerojet Utility van	Aerojet harness
d	Pacific Intermountain Express (PIE) van	PFRT (TBC) harness*
e	TBC van	TBC operational harness

2. Test Motors

The following Minuteman second-stage motors were used in the van-harness certification tests:

a. Motor 44SX-6 was used for the testing of van-and-harness combinations a through d. The motor was of the Wing I PFRT configuration, except for the aft-closure propellant.

b. Motor 44ME-4 was used in the plank-strip test of the TBC van-and-harness combination. The motor was of the Wing I qualification-test configuration and was successfully fired on 6 August 1962.

c. Motors 44QT-15 and -16 were used as test motors for the 96-mile rough-road test of the TBC van-harness combination. Motors 44QT-15 and -16 were statically fired on 23 May 1962 and 24 August 1962, respectively.

d. Wing I motors 44SX-6, 44ME-3, and 44ME-8 were used in additional plank-strip course tests of the Aerojet Utility van and the Aerojet harness. The test conditions were more severe than those in preceding van-certification-program tests and imposed high-level accelerations. After these additional tests, motor 44SX-6 was fired on 7 March 1962, motor 44ME-3 was

*Original Boeing-designed harness used for transporting motors in the PFRT program.

III, A, Test Units (cont.)

fired on 5 March 1962, and motor 44ME-8 was fired 27 July 1962. Each motor performed satisfactorily in full-duration firings.

B. INSTRUMENTATION AND DATA RECORDING

1. Accelerometer Instrumentation

Instrumentation of van, harness, and motor is shown in Figures 1 and 2. Figure 1 shows the 12 accelerometer locations used for van-and-harness combinations a through d.

Figure 2 shows the instrumentation locations as modified for the plank-strip-course test of the TBC van and harness. The BGS 107 alarm set and the oscillographic accelerometers were compared in conjunction with this test. Data obtained from six accelerometer locations are shown in Table 1.

Six accelerometers were used in the 96-mile rough-road test of the TBC van and operational harness with motors 44QT-15 and -16. Accelerometer-response data from these tests are shown in Tables 2 and 3.

Two types of strain-gage accelerometers were used for the van-harness certification tests. The instrumentation manufacturer and model numbers were:

a. Consolidated Electrodynamics Corp. (CEC), Model 4-202, 350 ohms $\pm$ 5 g, 0 to 200 cycles/sec.

b. Statham Instruments, Model 4A-15-350, $\pm$ 15 g, 0 to 200 cycles/sec.

III, B, Instrumentation and Data Recording (cont.)

2. Data-Recording System

The data-recording system consisted of a strain-gage bridge balance and calibration unit, CEC model 8-108, and a recording oscillograph, CEC Model 5-116, P3-14 with Model 7-341 galvanometers. An auxiliary power supply for operating the system provided both 28-v dc and 110-v ac.

Figure 3 shows the shock-isolation mounting of the recording equipment in the aft end of the van for van-harness combinations a through d. For the test of combination e and the additional high-level-acceleration tests described in section III. C. 5, the data-recording equipment was placed in a shock-isolation mounting on the bed of an accompanying truck. Cables from the van to the truck connected the accelerometers to the recording equipment. The truck was driven over a smooth road that paralleled the plank-strip course. Figure 4 shows the van-to-truck cable connection.

C. TEST CONDITIONS

1. General

The five van-harness combinations shown in section III. A. 1 were subjected to a series of essentially identical plank-strip-course tests and to a 96-mile rough-road test during the period ranging from 8 November 1961 to 6 June 1962. In addition, the Aerojet Utility van-harness combination was subjected to a series of plank-strip-course tests that provided a high level of acceleration input on the motor and harness.

The plank-strip-course tests, at Aerojet, Sacramento, provided a method of determining the dynamic-response characteristics of the van-harness-motor combinations for specific discrete frequencies and input acceleration levels. The 96-mile rough-road test was conducted over rougher roads than

III, C, Test Conditions (cont.)

would be normally encountered during the transportation of Minuteman second-stage motors and provided random acceleration inputs. Instrumentation of the van-harness-motor combinations was similar. The vibration responses at selected locations were recorded and the data were evaluated.

2. Plank-Strip Course 0.25-in.-High

The 0.25-in.-high plank-strip course was laid with plywood boards 8 in. wide and 0.25 in. thick. A 200-ft length of the course was used for tests of van-harness combinations a through d. A 100-ft length of the course was used to test the TBC van and TBC operational harness. Figure 5 shows the 200-ft section of the 0.25-in.-high plank-strip course, indicating the type of construction and installation used for all Aerojet board courses.

Spacing of the 0.25-in.-high plank strips was adjusted to subject the van being tested to a sinusoidal input vibration that would excite the van in the vertical mode. A board spacing of 22.8 $\pm$0.1 in. was used for tests of the Aerojet Utility van and the TBC transporter. A board spacing of 24.8 $\pm$0.1 in. was used for tests of the PIE van.

Van speeds were selected to ensure that the van-and-harness combinations would be subjected to an input frequency range that would result in significant resonances. Nominal speeds varied from 4 to 30 mph in increments of 2, 4, and 5 mph.

Additional runs over the plank course were made at 36 and 40 mph for the TBC transporter and operational harness.

To maintain a constant speed over the plank-strip course, the van driver maintained the specified vehicle speed during the approach to the course.

III, C, Test Conditions (cont.)

Immediately before the truck made contact with the first plank, the driver locked the hand throttle in the position that would maintain the desired speed during the run over the course. The actual speed of the van over the course differed slightly from the specified speed in many instances. The specified van speeds and the actual applied frequencies as determined from the recorded vibration data are presented in the data tabulations (Table 1 and Tables 4 through 12).

3. Plant-Strip Course 0.50-in. -High

The 0.50-in. -high plank-strip course was laid with boards 8 in. wide and 0.50 in. thick. Figure 6 shows the course.

Spacing of the 0.50-in. -high planks was the same as that of the 0.25-in. -high plank-strip course. The specified speeds also were identical to those specified for the tests over the 0.25-in. -high plank-strip course.

4. Ninety-six-Mile Rough-Road Course

The 96-mile rough-road course consisted of secondary roads in the vicinity of the Aerojet Sacramento plant. Figure 7 shows a map of the rough-road course on which the check points are indicated. Table 13 shows the course check points, the distance of the check points from the starting point, distances over which continuous data recordings were made, the speed at which the truck was driven at data-recording points, and a description of the road conditions at the data-recording points. The data-recording points were selected to represent the different road conditions that might be encountered during highway transportation of Minuteman second-stage motors. The course included railway crossings, rutted sections of dirt and gravel, pot holes, sections of washboard road, uneven bridge approaches, and surfaced roads that were cracked and deteriorated.

III, C, Test Conditions (cont.)

5. Additional High-Level Acceleration Tests

The additional high-level acceleration tests to which the Aerojet Utility van and universal harness and second-stage motors were subjected were as follows:

a. Plank Strip Course (1.125-in. -High)

The 1.125-in. -high course was laid with planks 8 in. wide and 1.125 in. thick placed 22.9 in. apart. The length of the course was 100 ft, and the vehicle speed ranged from 10 to 14 mph.

b. Plank-Strip Course (1.375-in High)

The 1.375-in. -high course was 100 ft long and was laid with planks 8 in. wide and 1.375 in. thick. Two Aerojet van-harness and second-stage motor combinations were subjected to tests in which the planks were placed 22.9 in. apart. A third van-harness-motor combination was subjected to tests over planks that were spaced 26.6 in. apart. The wider-space intervals caused a pitching motion of the van at higher acceleration loads. Vehicle speed ranged from 11.5 to 17 mph.

c. Calibration Test Runs

Before and after each 1.125- and 1.375-in. -high plank-strip-course test, additional tests were made over the 0.25-in. -high, 8-in. -wide planks spaced 22.9 in. apart. These tests were conducted to calibrate instrumentation and to correlate results with data obtained from previous transportation environmental tests.

III, Technical Discussion (cont.)

D. TEST RESULTS AND ANALYSES

1. Plank-Strip Course Tests (0.25- and 0.50-in.High)

The recorded acceleration-response data from the five van-harness-motor combinations subjected to the 0.25- and 0.50-in. -high plank-strip tests have been reduced. The reduced data are presented in Table 1 and Tables 4 through 12. Curves of the acceleration responses of accelerometer G2X (forward closure) from plank-strip tests of all five van-harness combinations were plotted on a one-graph field to compare acceleration levels at this location on the motors (Figures 8 and 9). Similar comparative graphs were completed for accelerometers G4X (Figures 10 and 11) and G6X (Figures 12 and 13) on the cases and aft closures of the test motors. A comparison for aft closure, forward head, and chamber acceleration-response levels is shown in Table 14.

The acceleration-response measurements in the tables represent maximum steady-state acceleration levels recorded at the accelerometer positions on the motor, van, or harness. Transient response readings of the accelerometers were taken as the van started and finished the plank-strip course. These data were not included in the final tables and curves.

The vibration frequencies shown in the tables and curves represent an average value of the system response frequency for a given run over the plank-strip course. The average value of the response frequencies was obtained from measurements made at the beginning, the middle, and the end of each run over the course. The variation of response frequency during a pass of the van over the course was due to the difficulty of maintaining a constant van speed.

III, D, Test Results and Analyses (cont.)

The maximum response (in the vertical direction) measured at the forward closure of the motor with accelerometer G2X occurred during the plank-strip-course tests of the Aerojet Utility van–Aerojet harness combination. Maximum acceleration levels of 1.09 g (over the 0.25-in. -high planks) and 1.95 g (over the 0.50-in. -high planks) were recorded at a van speed of 14.8 mph. This corresponds to a vibration frequency of 11.4 cycles/sec.

The plank-strip-course tests of the Aerojet Utility van with the TBC operational harness (with and without the Autonetics Phase IV NCU attached to the motor) revealed that the vibration response of the motor with the NCU attached was not significantly different from the response of the motor without the NCU installed. Response acceleration levels for accelerometers G2X and G6X measured over the 0.25-in. -high plank-strip tests of the Aerojet Utility van–TBC operational harness combination with the NCU attached to the motor were 0.68 g at 6.1 cycles/sec and 0.78 g at 7.5 cycles/sec, respectively. When the NCU was not attached to the motor, response acceleration levels at locations G2X and G6X were 0.59 g at 6.5 cycles/sec and 0.86 g at 7.7 cycles/sec, respectively.

The response acceleration levels of the PIE van–PFRT (TBC) harness combination were generally lower (frequency range of 4 to 10 cycles/sec) than the response acceleration levels obtained with other van-harness combinations. The highest response acceleration levels (not exceeding 1 g) for this test configuration were measured in the frequency range of 12 to 15 cycles/sec. Apparently, the tire-bounce mode of the PIE van was excited by this range of applied frequencies. Acceleration levels on the motor transported by the PIE van tended to increase at low van speeds.

III, D, Test Results and Analyses (cont.)

The maximum vertical response acceleration level that was measured at the G6X accelerometer position on the aft closure was 1.66 g, which corresponds to a frequency of 8.5 cycles/sec. This maximum level was recorded during the 0.50-in. -high plank-strip course test of the Aerojet Utility van with the TBC operational harness.

The acceleration response levels recorded at the G3X accelerometer position on the forward harness end ring were higher for the Aerojet Utility van–Aerojet harness combination than for other combinations tested. A response acceleration level of 1.56 g was recorded at the accelerometer position on the harness at an indicated speed of 14 mph, which corresponds to a frequency of 11.4 cycles/sec over the 0.50-in. -high planks.

A maximum value of 1.29 g was recorded at the G6X accelerometer position on the aft closure of the motor over the 0.50-in. -high plank-strip-course tests of the TBC van with the TBC operational harness. This maximum value of 1.29 g was measured at a nominal van speed of 14 mph, corresponding to a frequency of 9.74 cycles/sec.

2. 96-Mile Rough-Road Tests

Oscillographic recordings of all channels of accelerometer instrumentation were made for each check point along the rough-road test course (Tables 15 through 17).

The response acceleration levels measured during the road-course tests were generally less than the levels recorded over the 0.50-in. -high plank-strip-course tests of the five different van-harness combinations. At the rough-road-course check points, representing extreme conditions (Table 13), the response acceleration levels were slightly higher than the maximum levels recorded on the 0.50-in. -high plank-strip course.

III, D, Test Results and Analyses (cont.)

3. Plank-Strip Course Tests (1.125- and 1.375-in. -High)

Motor 44ME-3, supported in an Aerojet harness, was subjected to 100 cycles of approximately 3-g acceleration while being transported by an Aerojet Utility van over the 1.125-in. -high plank-strip course. Twenty-four recorded values were greater than 3 g. Acceleration forces recorded on the forward head included 14 readings between 2.5 and 3 g; 13 between 3 and 3.5 g; seven between 3.5 and 4 g; and four readings between 4 and 4.1 g.

In combination with the Aerojet Utility van and Aerojet harness, motor 44SX-6 was subjected to 1000 cycles of high-level acceleration over the 100-ft-long 1.125-in. plank-strip course. Analysis of test data indicated that 426 cycles were recorded at 2.5 g or higher. Four of the 426 cycles were recorded at 4.6 g, the maximum level recorded for motor 44SX-6.

The maximum acceleration load recorded on any motor case during the transportation environmental tests was that obtained in tests of motor 44ME-8, which was the only motor subjected to the 1.375-in. -high board-course test. Seventeen tests were conducted over the course with the motor supported by an Aerojet harness and transported in an Aerojet Utility van. The motor case was subjected to 82 cycles of acceleration loads ranging from 4 to 8.4 g. Readings greater than 4 g were:

Number of Values Recorded	Accelerometer Range, g
41	4 to 4.99
23	5 to 5.99
10	6 to 6.99
6	7 to 7.99
2	8 to 8.38

IV. CONCLUSIONS

The maximum acceleration-response levels that were recorded on the motor for the five different van-harness combinations during the 0.25- and 0.50-in. -high plank-strip course and the 96-mile rough-road tests were less than the 3-g design load of the second-stage Minuteman motor.

The additional and more severe road tests of motors 44SX-6, 44ME-3, and 44ME-8 with the Aerojet Utility van and Aerojet harness were successfully completed. Motors 44SX-6, 44ME-3 and -8 performed satisfactorily in full-duration firings after these additional tests.

Test results obtained from the Van Certification program indicate that the Aerojet Utility van (Figure 14) is acceptable for use as a transport vehicle for second-stage Minuteman motors.

Test results show that the 0.50-in. -high plank-strip course (with the planks properly spaced) imposes acceleration levels that are equal to or greater than those during the 96-mile road tests.

TABLE 1

RESPONSE ACCELERATION DATA FROM 0.50-in. PLANK-STRIP TEST OF TBC VAN AND TBC OPERATIONAL HARNESS*

Indicated Speed MPH	Frequency Cycles/sec	Maximum Acceleration ±G Response at Accelerometer Locations 3Y	2X	3Z	5Y	6X	5Z
6	5.24	.27	.64	.19	.27	.39	.13
8	6.69	.33	.54	.11	.32	.73	.09
10	7.44	.31	.35	.11	.28	.76	.09
12	8.59	.58	.18	.22	.45	.99	.22
14	9.76	.51	.51	.27	.45	1.12	.28
16	12.1	.33	.31	.28	.30	.73	.20
20	17.9	.20	.19	.14	.19	.24	.14
25	19.4	.22	.22	.16	.16	.18	.13

* Test conducted in conjunction with checkout of BGS 107 alarm set with motor 44ME-4

TABLE 2

RESPONSE ACCELERATION DATA FROM 96-MILE ROUGH-ROAD TEST OF TBC VAN AND OPERATIONAL HARNESS *

Check Point	Maximum Recorded Acceleration ±G Response					
	G2X	G3X	G4X	G5X	G9X	G9Z
3	1.20	1.03	.94	1.65	1.85	1.22
4	.52	.45	.37	.92	1.04	.73
5	.72	.55	.32	.78	1.04	.60
6	.69	.68	.62	1.24	1.52	.80
7	.76	.74	.49	.92	1.15	.80
8	.51	.61	.77	1.01	1.44	.97
9	.69	.55	.62	.78	.94	.95
10	1.14	1.26	1.16	2.07	2.52	1.33
11	.41	.36	.47	.92	1.13	.77
12	.69	.68	.40	.92	1.11	.80
13	.34	.48	.74	1.15	1.55	1.02
14	.41	.42	.69	.92	1.79	1.15
15	.69	.65	.52	.87	1.11	.80

* With motor 44QT-15

TABLE 3

RESPONSE ACCELERATION DATA FROM 96-MILE ROUGH-ROAD OF TBC VAN AND OPERATIONAL HARNESS *

Check Point	Maximum Recorded Acceleration ±G Response					
	G2X	G3X	G4X	G5X	G9X	G9Z
3	.92		.54	.70	.95	.57
4	.85		.43	.60	.76	.45
5	.68		.42	.95	.30	.29
6	.78		.35	.64	.84	.38
7	.51	No Calibration	.57	.88	.95	.35
8	.44		.35	.53	.57	.37
9	.89		.72	1.06	1.14	.88
10	.55		.50	.53	.69	.41
11	.41		.33	.64	.76	.27
12	1.09		1.15	1.91	2.29	.61
13	.51		.52	.70	.95	.34
14	1.06		.83	1.41	1.52	.45
15	.75		.62	1.06	1.10	.35

* With motor 44QT-16

TABLE 4

RESPONSE ACCELERATION DATA FROM 0.25-in. PLANK-STRIP TEST OF AEROJET UTILITY VAN WITH TBC OPERATIONAL HARNESS (SECOND-STAGE MOTOR WITHOUT NOZZLE-CONTROL UNIT)

Indicated Speed MPH	Frequency Cycles/sec	Maximum Acceleration ±G Response at Accelerometer Locations											
		G1X	G2X	G2Z	G3X	G4X	G5X	G6X	G6Y	G7X	G7Y	G7Z	G8X
4	4.8	.29	.55	.06	.63	.22	.43	.44	.27	.21	.29	.12	.23
6	6.5	.29	.59	.16	.63	.23	.68	.75	.22	.25	.26	.16	.44
8	7.7	.34	.48	.08	.57	.30	.85	.86	.14	.48	.27	.19	.60
10	9.3	.66	.19	.06	.46	.34	.68	.81	.11	1.20	.53	.23	1.05
12	10.8	1.23	.26	.07	.46	.38	.56	.51	.10	1.50	.37	.25	1.45
14	12.6	.92	.27	.06	.40	.22	.34	.32	.05	1.41	.29	.19	1.16
16	14.4	.72	.16	.08	.40	.16	.24	.32	.09	1.16	.59	.33	.94
18	17.3	.82	.13	.10	.34	.23	.24	.28	.09	1.44	.84	.43	1.36
20	18.1	.79	.20	.09	.28	.20	.21	.23	.10	1.80	.93	.39	1.24
22	21.1	.72	.11	.07	.23	.16	.17	.28	.11	1.29	.64	.28	1.05
26	22.9	.50	.12	.05	.28	.14	.14	.29	.09	1.35	.56	.18	1.00
30	27.8	.66	.12	.05	.17	.11	.14	.23	.11	1.00	.25	.24	.77

TABLE 5

RESPONSE ACCELERATION DATA FROM 0.25-in. PLANK-STRIP TEST OF AEROJET UTILITY VAN WITH TBC OPERATIONAL HARNESS (NOZZLE-CONTROL UNIT INSTALLED ON MOTOR)

Indicated Speed MPH	Frequency Cycles/sec	Maximum Acceleration ±G Response at Accelerometer Locations											
		G1X	G2X	G2Z	G3X	G4X	G5X	G6X	G6Y	G7X	G7Y	G7Z	G8X
4	5.0	.40	.63	.11	.66	.29	.38	.41	.31	.45	.15	.31	.34
6	6.1	.44	.68	.15	.71	.29	.66	.61	.27	.49	.16	.30	.46
8	7.5	.36	.51	.18	.49	.39	.83	.78	.18	.73	.18	.20	.69
10	9.0	.73	.26	.11	.30	.39	.75	.75	.12	.85	.19	.41	1.03
12	10.2	1.06	.29	.12	.41	.55	.68	.61	.12	1.76	.25	.45	1.26
14	11.7	1.03	.23	.10	.26	.37	.40	.35	.09	1.33	.27	.39	1.03
16	14.5	.86	.15	.09	.23	.22	.27	.20	.12	1.09	.29	.49	.72
20	18.8	1.00	.23	.11	.30	.24	.29	.21	.34	1.51	.32	.82	1.14
25	22.3	.60	.15	.09	.23	.20	.16	.14	.17	1.15	.19	.43	.74
30	27.0	.59	.15	.08	.14	.14	.13	.11	.09	1.03	.19	.24	.72

TABLE 6

RESPONSE ACCELERATION DATA FROM 0.25-in. PLANK-STRIP TEST OF AEROJET UTILITY VAN WITH AEROJET HARNESS

Indicated Speed MPH	Frequency Cycles/sec	Maximum Acceleration ±G Response at Accelerometer Locations											
		G1X	G2X	G2Z	G3X	G4X	G5X	G6X	G6Y	G7X	G7Y	G7Z	G8X
4	4.8	.44	.52	.07	.44	.20	.26	.30	.15	.50	.16	.09	.28
6	6.3	.44	.49	.10	.44	.25	.28	.30	.08	.44	.25	.11	.28
8	6.4	.47	.49	.09	.45	.25	.28	.27	.09	.41	.25	.09	.31
10	7.3	.38	.44	.09	.41	.23	.32	.32	.08	.47	.30	.11	.33
12	9.3	.44	.47	.10	.45	.36	.45	.43	.27	.50	.41	.18	.47
14	11.4	.99	1.08	.15	1.03	.51	.61	.69	.38	.71	.85	.25	.72
16	13.2	.81	.99	.17	.93	.25	.65	.68	.22	.74	.66	.22	.45
18	15.1	.51	.73	.24	.63	.23	.79	.81	.31	1.12	1.11	.30	.95
20	16.1	.38	.47	.18	.40	.28	.69	.70	.27	.88	.99	.31	1.22
22	17.9	.38	.41	.15	.41	.29	.51	.54	.27	.94	.81	.27	1.00
26	20.0	.37	.36	.16	.41	.36	.38	.43	.23	.85	.56	.22	.64
30	25.6	.32	.30	.15	.27	.34	.28	.27	.14	.41	.42	.19	.70

TABLE 7

RESPONSE ACCELERATION DATA FROM 0.25-in. PLANK-STRIP TEST OF PIE VAN WITH TBC PFRT HARNESS

Indicated Speed MPH	Frequency Cycles/sec	Maximum Acceleration +G Response at Accelerometer Locations										
		G1X	G2X	G2Z	G3X	G4X	G5X	G6X	G6Y	G7X	G7Z	G8X
2	2.9	.45	.59	.04	.38	.18	.31	.23	.16	.20	.06	.22
4	3.5	.27	.31.	.02	.32	.11	.19	.20	.20	.30	.04	.16
6	4.4	.21	.31	.02	.26	.13	.19	.16	.21	.40	.04	.16
8	5.8	.27	.43	.02	.41	.20	.35	.32	.21	.45	.08	.49
10	6.9	.24	.31	.02	.32	.11	.24	.25	.15	.20	.06	.22
12	8.3	.30	.20	.06	.20	.15	.35	.41	.18	.40	.11	.32
14	9.2	.39	.20	.06	.17	.13	.26	.20	.20	.50	.21	.43
16	9.9	.72	.35	.12	.32	.11	.19	.16	.33	.50	.27	.70
18	11.6	1.38	.47	.08	.32	.29	.26	.16	.33	1.20	.44	1.46
20	13.5	1.44	.63	.06	.44	.37	.38	.36	.28	1.25	.21	.97
22	14.4	1.02	.27	.08	.22	.42	.59	.68	.44	1.55	.19	1.08
26	17.2	.48	.31	.10	.24	.24	.45	.39	.29	1.15	.19	.54
30	19.3	.18	.20	.04	.14	.11	.14	.21	.15	.65	.11	.27

TABLE 8

RESPONSE ACCELERATION DATA FROM 0.25-in. PLANK-STRIP TEST OF TBC VAN WITH TBC OPERATIONAL HARNESS*

Indicated Speed MPH	Frequency Cycles/sec	Maximum Acceleration ±G Response at Accelerometer Locations										
		4X	2X	3X	5X	6Z	2Y	9X	17X	9Z	6X	14X
2	2.99	.28	.29		.16	.08	.07	.11		.09	.30	.25
4	3.49	.30	.31		.16	.07	.06	.07		.10	.31	.09
6	3.86	.28	.29		.15	.07	.06	.22		.09	.30	.08
8	4.63	.25	.26		.15	.08	.08	.10		.10	.26	.11
10	8.08	.47	.49		.19	.65	.16	.21		.07	.52	.24
12	11.59	.63	.63		.27	.07	.14	.27		.09	.65	.20
14	15.61	.49	.51	No Data	.20	.06	.12	.23	No Data	.08	.52	.18
16	17.41	.30	.31		.22	.05	.10	.21		.07		.12
18	17.45	.29	.30		.17	.05	.10	.23		.07		.14
20	20.43	.17	.17		.27	.04	.07	.15		.05	No Data	.09
25	26.41	.14	.13		.17	.04	.05	.13		.06		.08
30	29.20	.13	.13		.23	.04	.05	.12		.04		.08

* With Motor 44ME-4

TABLE 9

RESPONSE ACCELERATION DATA FROM 0.50-in. PLANK-STRIP TEST OF AEROJET UTILITY VAN WITH TBC OPERATIONAL HARNESS

Indicated Speed MPH	Frequency Cycles/sec	Maximum Acceleration ±G Response at Accelerometer Locations											
		G1X	G2X	G2Z	G3X	G4X	G5X	G6X	G6Y	G7X	G7Y	G7Z	G8X
4	5.1	.43	.96	.14	1.03	.34	.65	.59	.47	.45	.43	.19	.44
6	6.4	.52	.98	.26	.91	.33	1.22	1.24	.43	.49	.36	.19	.83
8	7.6	.57	.87	.09	.80	.47	1.26	1.50	.47	1.32	.60	.34	1.47
10	8.5	1.17	.68	.14	.63	.84	1.33	1.66	.49	2.28	.88	.51	2.28
12	10.9	1.26	.47	.10	.63	.56	.80	.81	.18	2.27	.75	.65	1.98
14	12.9	.97	.41	.15	.57	.25	.54	.54	.18	2.07	.84	.51	1.60
16	14.0	.86	.27	.16	.57	.29	.54	.50	.21	1.91	1.06	.78	1.93
18	16.4	.93	.48	.15	.46	.26	.54	.54	.24	3.03	1.86	.66	1.93
20	19.0	1.00	.34	.12	.40	.37	.54	.44	.21	4.39	1.67	2.97	2.05
22	20.8	1.29	.18	.08	.40	.29	.54	.30	.21	4.06	1.57	.59	2.28
26	23.8	.86	.18	.06	.40	.15	.44	.40	.13	1.93	.93	.47	1.48
30	29.4	1.11	.16	.05	.24	.13	.32	.33	.11	2.05	.70	.50	1.36

TABLE 10

RESPONSE ACCELERATION DATA FROM 0.50-in. PLANK-STRIP TEST OF AEROJET UTILITY VAN WITH AEROJET HARNESS

Indicated Speed MPH	Frequency Cycles/sec	Maximum Acceleration ±G Response at Accelerometer Locations											
		G1X	G2X	G2Z	G3X	G4X	G5X	G6X	G6Y	G7X	G7Y	G7Z	G8X
4	4.6	.68	.71	.15	.66	.33	.26	.40	.22	.53	.24	.14	.45
6	6.0	.53	.58	.13	.49	.38	.38	.40	.10	.47	.33	.13	.45
8	6.6	.47	.49	.12	.44	.30	.38	.40	.10	.47	.31	.13	.45
10	7.7	.56	.66	.12	.58	.35	.51	.51	.27	.65	.53	.16	.56
12	9.8	1.02	1.10	.22	1.04	.76	.88	.89	.56	1.06	.85	.20	1.83
14	11.4	1.53	1.95	.40	1.56	.58	1.13	1.23	.42	1.65	1.22	.68	1.28
16	12.8	1.03	1.48	.41	1.45	.33	1.23	1.24	.34	1.21	1.44	.81	1.06
18	15.2	.88	.91	.44	.77	.43	1.05	1.11	.43	1.53	1.67	.61	1.53
20	16.2	.49	.69	.25	.58	.71	.87	1.19	.36	1.53	1.88	.67	2.28
22	24.4	.50	.58	.16	.62	.66	.85	.84	.32	1.23	1.33	.40	1.45
26	21.0	.50	.55	.16	.55	.67	.82	.84	.24	1.06	.97	.23	1.42
30	25.6	.37	.52	.16	.48	.53	.38	.40	.14	.53	.88	.43	1.42

TABLE 11

RESPONSE ACCELERATION DATA FROM 0.50-in. PLANK-STRIP TEST OF PIE VAN WITH TBC PFRT HARNESS

Indicated Speed MPH	Frequency Cycles/sec	Maximum Acceleration ±G Response at Accelerometer Locations										
		G1X	G2X	G2Z	G3X	G4X	G5X	G6X	G6Y	G7X	G7Z	G8X
2	3.0	.72	.98	.08	.90	.29	.45	.57	.37	.50	.17	.60
4	3.6	.42	.51	.02	.46	.18	.24	.27	.31	.45	.11	.22
6	4.4	.48	.59	.14	.58	.26	.26	.25	.37	.55	.11	.27
8	5.3	.54	.59	.08	.55	.33	.45	.41	.36	.85	.11	.65
10	7.0	.60	.47	.08	.44	.22	.42	.45	.24	.65	.15	.54
12	7.4	.57	.43	.06	.38	.20	.38	.41	.24	.80	.21	.65
14	9.1	.99	.31	.12	.32	.13	.26	.20	.54	.90	.49	1.30
16	9.2	.99	.35	.08	.35	.15	.24	.23	.57	.90	.44	1.57
18	11.4	1.91	.86	.16	.93	.51	.28	.21	.46	2.00	.68	2.27
20	11.8	1.79	.98	.12	.90	.51	.31	.29	.46	2.00	.72	2.27
22	14.5	1.10	.47	.14	.38	.46	.87	.82	.54	1.65	.23	1.08
26	15.4	1.10	.59	.08	.46	.42	.92	.68	.52	1.55	.30	.97
30	18.9	.21	.27	.06	.29	.11	.19	.29	.20	1.05	.13	.43

TABLE 12

RESPONSE ACCELERATION DATA FROM 0.50-in. PLANK-STRIP TEST OF TBC VAN WITH TBC OPERATIONAL HARNESS*

Indicated Speed MPH	Frequency Cycles/sec	Maximum Acceleration ±G Response at Accelerometer Locations									
		2X	3X	5X	6Z	2Y	9X	17X	9Z	6X	14X
6	5.52	.76	.78	.47	.14	.13		.46		.48	
8	6.77	.57	.64	.77	.11	.13		.39		.77	
10	7.41	.40	.44	.79	.10	.12		.46		.87	
12	8.57	.14	.34	1.14	.20	.27	No Data	.88	No Data	1.14	No Data
14	9.74	.45	.64	1.24	.12	.26		1.46		1.29	
16	11.85	.30	.31	.80	.16	.14		1.60		.85	
20	17.64	.18	.28	.23	.10	.09		.72		.23	
25	18.92	.20	.35	.25	.11	.09		.85		.22	

* With Motor 44ME-4

TABLE 13

NINETY-SIX-MILE ROUGH-ROAD-TEST CHECK POINTS FOR DATA RECORDING

Check Point	Miles from Check Point to Gate 7	Length of Recording Data (Miles)	Truck Speed When Recording Data (MPH)	Description of Road
1	0			Gate 7, at Aerojet, Sacramento
2	1.8	0.7	10 → 20	0.50 to 0.75 in. Pot holes; rocks on rough dirt road protrude up to 2 in.
3	4.1	0.2	15	Hill on rough dirt road, random size rocks
4	5.2	0.05	15	Rough railroad two-track crossing; intersection of White Rock Road and Payne
5	7.1	0.1	30	Culvert with 1 in. x 8 ft long concrete (step input). Stop at Latrobe Road
6	7.2	0.2	20	Paved rough winding road from Latrobe Road stop sign
7	15.1	0.15	25	Paved rough road and railroad crossing
8	18.1	0.2	20	Downgrade over road having 0.375 in. obstructions and small bridge
9	18.6	0.2	10	Small bridge; dirt road with 0.75 in. rocks; Consumnes River bridge smooth concrete
10	38.8	0.6	40	Average paved road at maximum speed
11*	62.2	0.1	10	Three pot holes at R.H. side of road in series. Average hole 1 in. x 10 ft W x 20 ft L
12	64.7	0.15	15	Railroad crossing and curve
13	66.2	0.1	8	Gravel road with 0.75 in. obstructions
14	71.8	0.2	20	Two culverts, 1.50 in. deep by 8 ft long. Stop on Highway 16
15	86.9	0.15	30	Paved rough road with 0.375 in. chuck holes

* Chuck holes were paved prior to test

TABLE 14

MAXIMUM VERTICAL RESPONSE ACCELERATION LEVELS AT SPECIFIED MOTOR LOCATIONS (MOTOR WITH NCU)

Van-Harness Combination		Fwd Closure (G2X)		Aft Closure (G6X)		Chamber, Top Center (G4X)	
Van	Harness	1/4 in.	1/2 in.	1/4 in.	1/2 in.	1/4 in.	1/2 in.
1. AGC -	AGC Universal	1.1	2.0	0.8	1.2	0.5	0.8
2. AGC -	TBC Operational	0.6	1.0	0.9	1.7	0.4	0.8
3. *AGC -	TBC Operational	0.7	--	0.8	--	0.6	--
4. PIE -	TBC PFRT	0.6	1.0	0.7	0.8	0.4	0.5
5. TBC -	TBC Operational	0.6	0.8	0.7	1.3	0.6	--

* With NCU

TABLE 15

RESPONSE ACCELERATION DATA FROM 96-MILE ROAD TEST OF AEROJET UTILITY VAN WITH TBC OPERATIONAL HARNESS*

Check Point	Maximum Acceleration ± Response at Accelerometer Locations											
	G1X	G2X	G2Z	G3X	G4X	G5X	G6X	G6Y	G7X	G7Y	G7Z	G8X
2	.72			.93		.65	.79	.33				
3	.51			.48		.36	.42	.28				
4	.75	No Data		.78	No Data	.51	.51	.28	No Data	No Data	No Data	No Data
5	.58			.60		.40	.49	.26				
6	1.0		NO CALIBRATION	.84		.62	.79	.28				
7	.64			.42		.51	.44	.21				
8	.54	.40		.48	.24	.40	.34	.21	.51	.32	.29	.47
9	.72	.80		.72	.52	.57	.67	.22	.67	.32	.32	.65
10	.39	.37		.39	.26	.32	.34	.20	.37	.27	.33	.42
11	.32	.40		.42	.26	.36	.34	.20	.37	.21	.28	.30
12	.37	.67		.66	.25	.62	.79	.29	.66	.41	.32	.63
13	.22	.44		.44	.16	.28	.29	.20	.20	.22	.28	.22
14	.38			.33		.31	.41	.24		No Data		

* With Motor 44SX-6

TABLE 16

RESPONSE ACCELERATION DATA FROM 96-MILE ROAD TEST OF AEROJET UTILITY VAN WITH AEROJET HARNESS

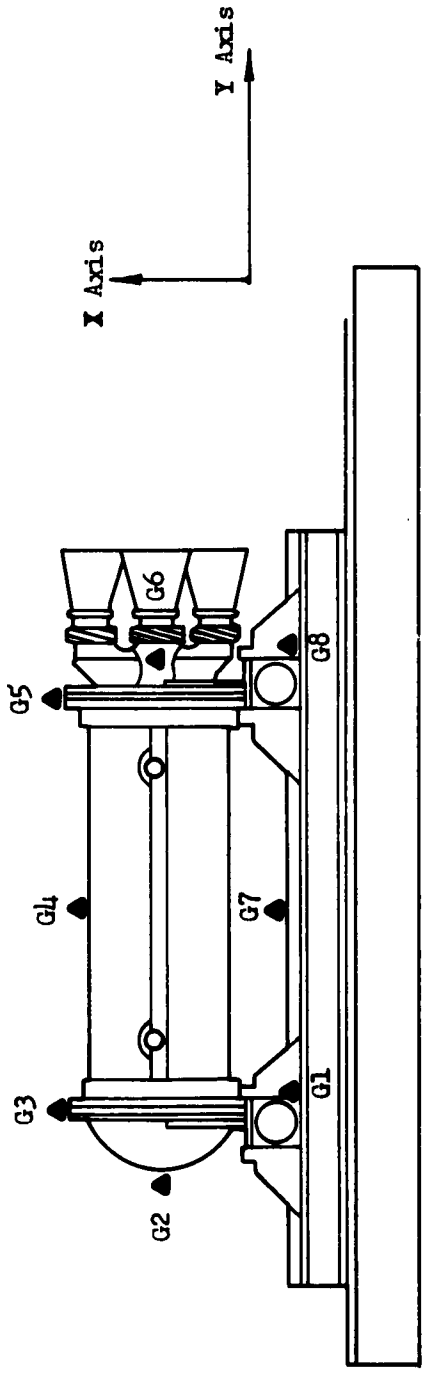
Check Point	MAXIMUM RECORDED ACCELERATION ±G RESPONSE										
	G 1 X	G 2 X	G 2 Z	G 3 X	G 4 X	G 5 X	G 6 X	G 6 Y	G 7 X	G 7 Z	G 8 X
2	.37	.46	.33	.46	.29	NO CALIBRATION DATA	.60	.28	NO DATA RECORDED	.38	.52
3	.94	1.54	.43	1.42	.70		1.18	.51		1.20	1.35
4	.58	.46	.33	.54	.30		.60	.21		.31	.61
5	.41	.84	.51	.46	.29		.66	.31		.49	.54
6	.49	.58	.20	.44	.18		.60	.24		.31	.52
7	.49	.73	.20	.60	.32		.62	.24		.40	.61
8	.45	.51	.33	.45	.30		.42	.15		.31	.48
9	.70	1.13	.40	1.32	.56		.72	.31		.67	.57
10	.55	.48	.25	.49	.37		.62	.26		.33	.63
11	.48	.46	.35	.81	.56		.92	.23		.47	.78
12	.45	.58	.34	.57	.32		.40	.09		.22	.48
13	1.06	1.35	.22	1.20	.54		1.14	.35		.89	.80
14	.33	.36	.18	.24	.15		.24	.09		.13	.26
15	.49	.62	.20	.57	.22		.54	.23		.36	.48

TABLE 17

RESPONSE ACCELERATION DATA FROM 96-MILE ROAD TEST OF PIE VAN WITH TBC PFRT HARNESS

Check Point	MAXIMUM RECORDED ACCELERATION ±G RESPONSE										
	G 1 X	G 2 X	G 2 Z	G 3 X	G 4 X	G 5 X	G 6 X	G 6 Y	G 7 X	G 7 Z	G 8 X
2	.46	.61	-	.61	.28	.65	.64	.39	.73	.18	.78
3	-	-	-	.23	.12	.26	.45	.29	.35	.10	.49
			NO DATA RECORDED								
5	.30	.67	-	.58	-	.47	.50	.23	.85	.19	.76
6	.30	.39	.10	.33	.20	.40	.40	.22	.40	.13	.43
7	.42	.59	-	.61	.32	.47	.48	.31	.65	.13	.54
8	-	.33	-	.32	-	.24	.30	.16	.40	-	.38
9	.49	.92	-	.87	.55	.67	.67	.44	.95	.24	.70
10	.18	.35	.12	.32	.15	.36	.45	.28	.60	.13	.54
11*	-	.20	-	.17	.11	.19	.18	.08	-	-	-
12	.63	1.18	.15	1.07	.42	.75	.77	.58	.95	.15	.76
13							.22	.16	.33	-	-
14			NO DATA RECORDED				.33	.23	.33	-	.35
15							.42	.28	.50	.13	.54

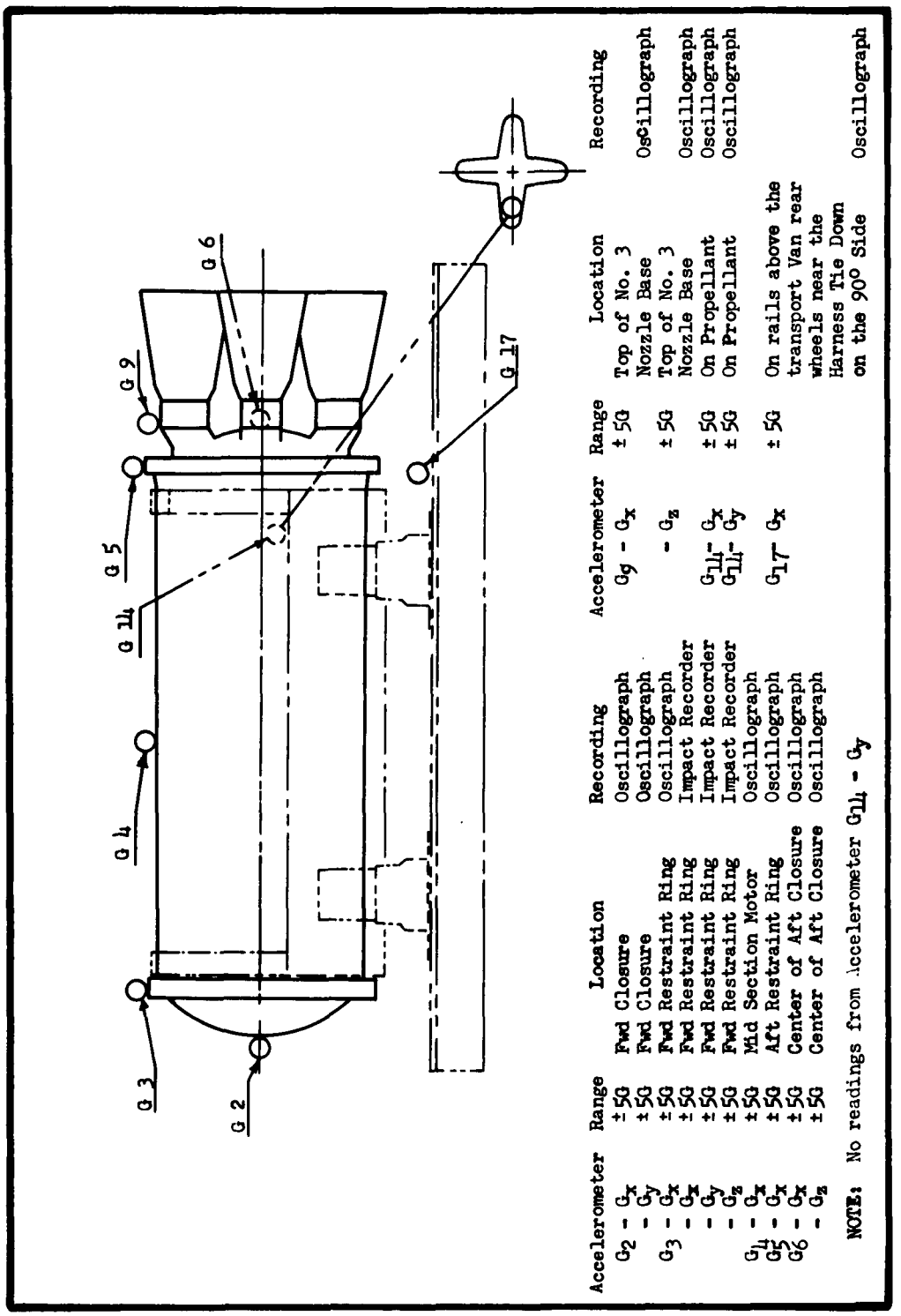
* Chuck holes were paved prior to test (See Table)



Accelerometer	Range	Location	Recording
G1X	±3G	Forward Tie down left side	Oscillograph
G2X	±3G	Forward Closure	
G2Z	±2G	Forward Closure	
G3X	±3G	Forward Restraint Ring (top)	
G4X	±3G	Top Center of Engine	
G5X	±3G	Aft Restraint Ring (top)	
G6X	±3G	Aft Closure Center	
G6Y	±2G	Aft Closure Center	
G7X	±3G	Truck bed Center of Engine	
G7Y	±2G	Truck bed Center of Engine	
G7Z	±2G	Truck bed Center of Engine	
G8X	±3G	Aft Tie Down Right Side	Oscillograph

Location of Response Accelerometers

Figure 1



Accelerometer	Range	Location	Recording	Accelerometer	Range	Location	Recording
G_2 - G_x	±5G	Fwd Closure	Oscillograph	G_9 - G_x	±5G	Top of No. 3	
- G_y	±5G	Fwd Closure	Oscillograph			Nozzle Base	Oscillograph
G_3 - G_x	±5G	Fwd Restraint Ring	Oscillograph	- G_z	±5G	Top of No. 3	
- G_x	±5G	Fwd Restraint Ring	Impact Recorder			Nozzle Base	Oscillograph
- G_y	±5G	Fwd Restraint Ring	Impact Recorder	G_{14} - G_x	±5G	On Propellant	Oscillograph
- G_z	±5G	Fwd Restraint Ring	Impact Recorder	G_{14} - G_y	±5G	On Propellant	Oscillograph
G_4 - G_x	±5G	Mid Section Motor	Oscillograph				
G_5 - G_x	±5G	Aft Restraint Ring	Oscillograph	G_{17} - G_x	±5G	On rails above the transport Van rear wheels near the Harness Tie Down on the 90° Side	Oscillograph
G_6 - G_x	±5G	Center of Aft Closure	Oscillograph				
- G_z	±5G	Center of Aft Closure	Oscillograph				

NOTE: No readings from Accelerometer G_{14} - G_y

Accelerometer Locations for Oscillograph Recordings for Plank-Strip Test of TBC Van and Harness With Motor 44ME-4

Figure 2

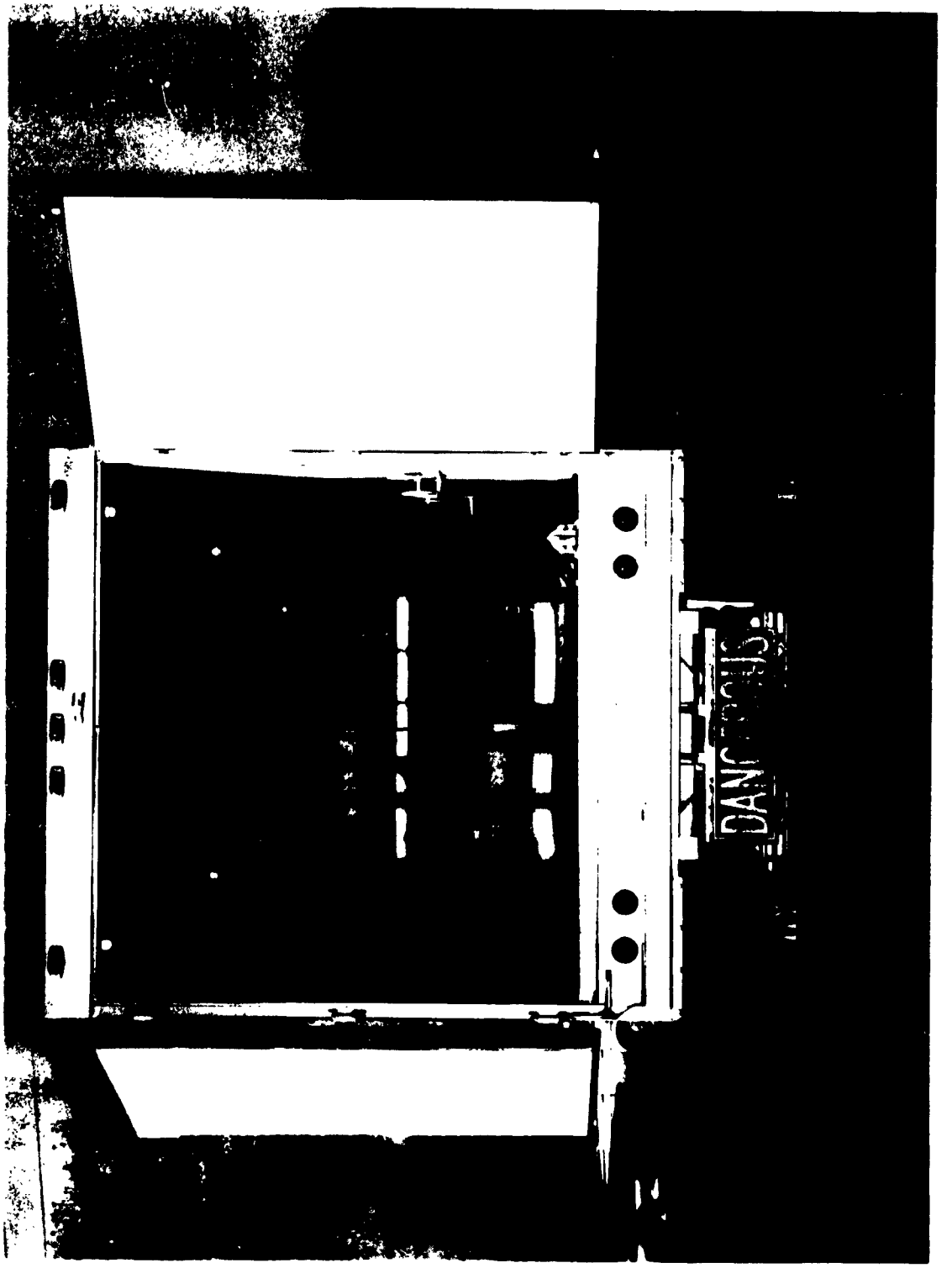
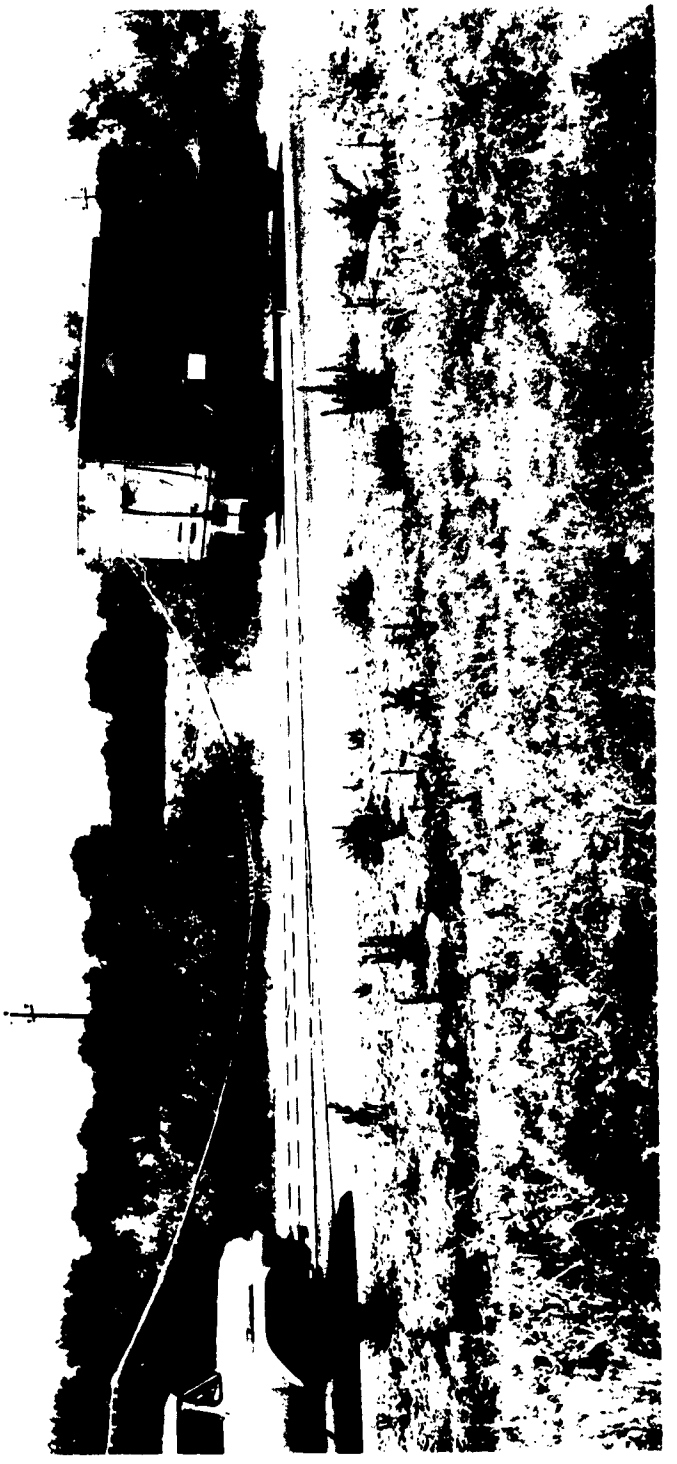


Figure 3



Van-to-Truck Cable Connection

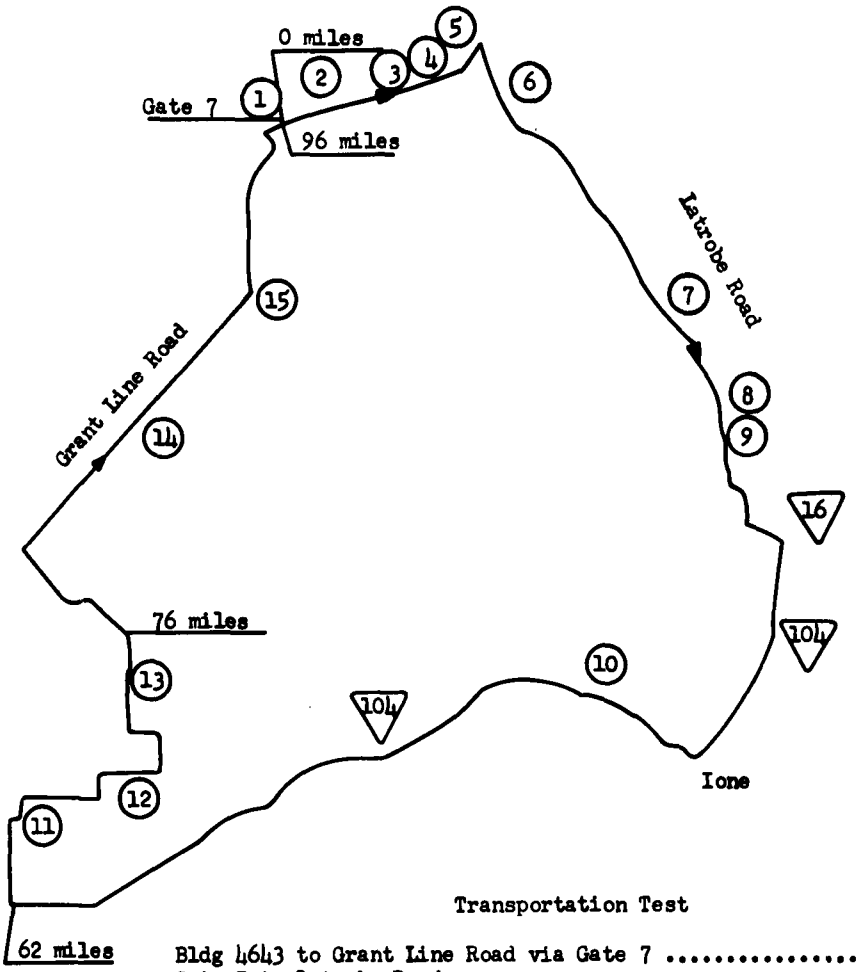
Figure 4

Plank-Strip Course Installation (0.25-in.-High Plank Strips, 200-ft Course Length)

Figure 5

Plank-Strip-Course Test Site at Aerojet-General, Sacramento

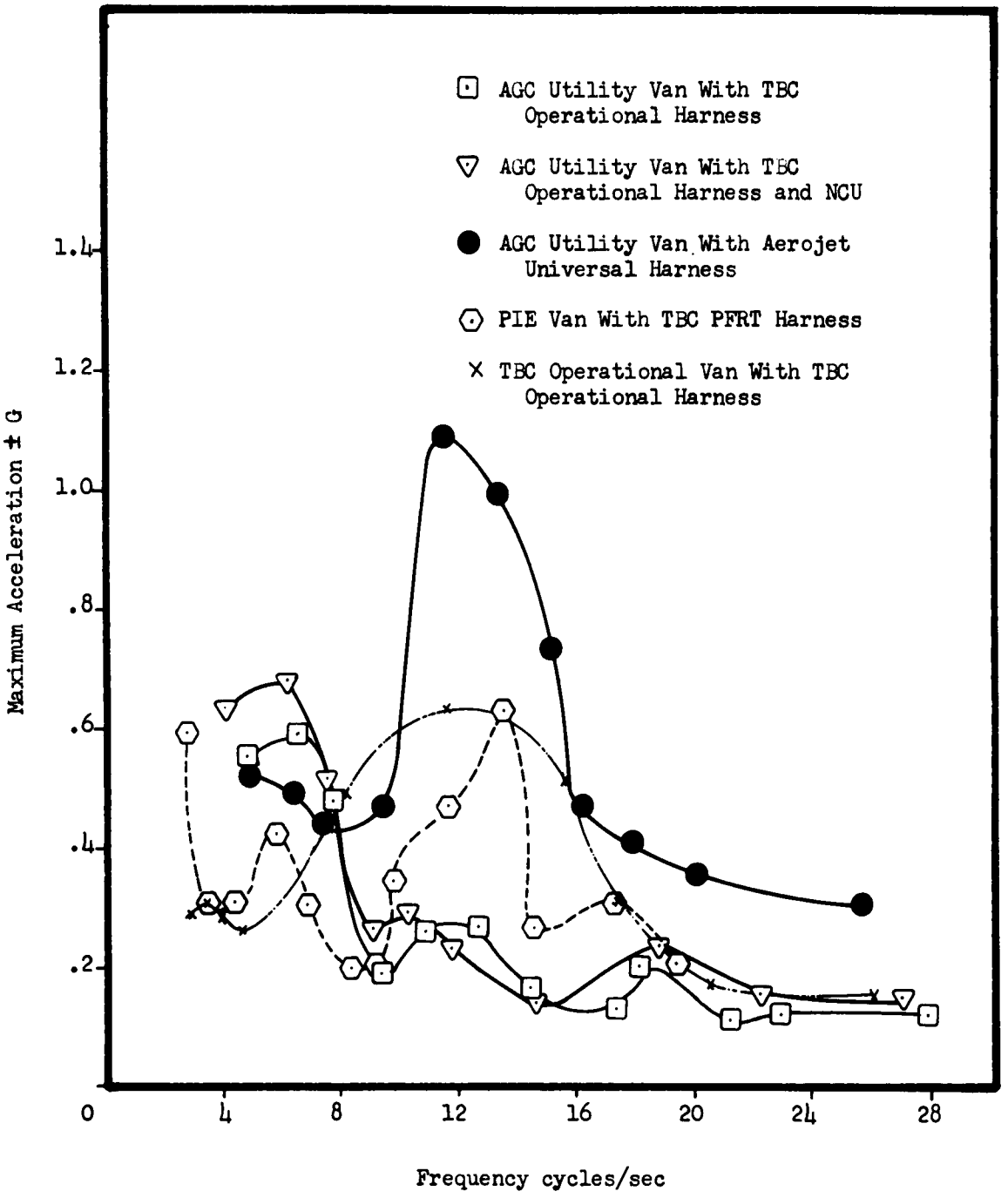
Figure 6



Transportation Test	Approx miles
Bldg 4643 to Grant Line Road via Gate 7	3.0
Gate 7 to Latrobe Road	8.0
Right on Latrobe Road to Highway 16	8.5
Left on Highway 16 to Highway 104	8.8
Right on Highway 104 to Ione	8.9
Right in Ione remaining on Highway 104 to McKenzie Road	23.7
Right on McKenzie to Arno Road	2.5
Right on Arno Road to Alta Mesa Road	8.5
Left on Alta Mesa Road to Woods Road	1.1
Left on Woods Road to Colony Road	1.0
Right on Colony Road to Randolph Road	3.5
Left on Randolph Road to Wilton to Grant Line Road	1.5
Right on Grant Line Road to AGC Truck Terminus via Gate 7.	21.0

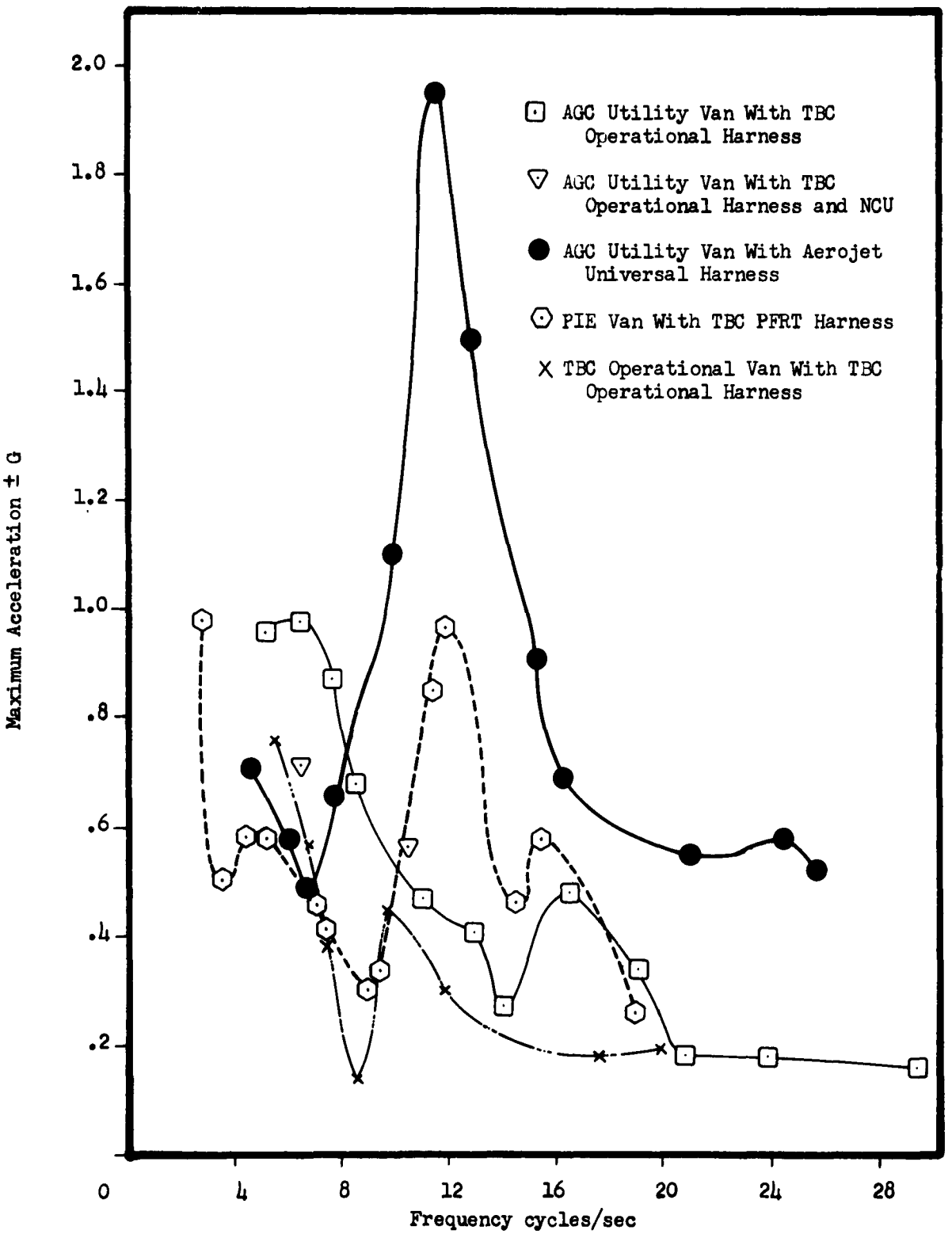
Map of 96-Mile Rough Road Test

Figure 7



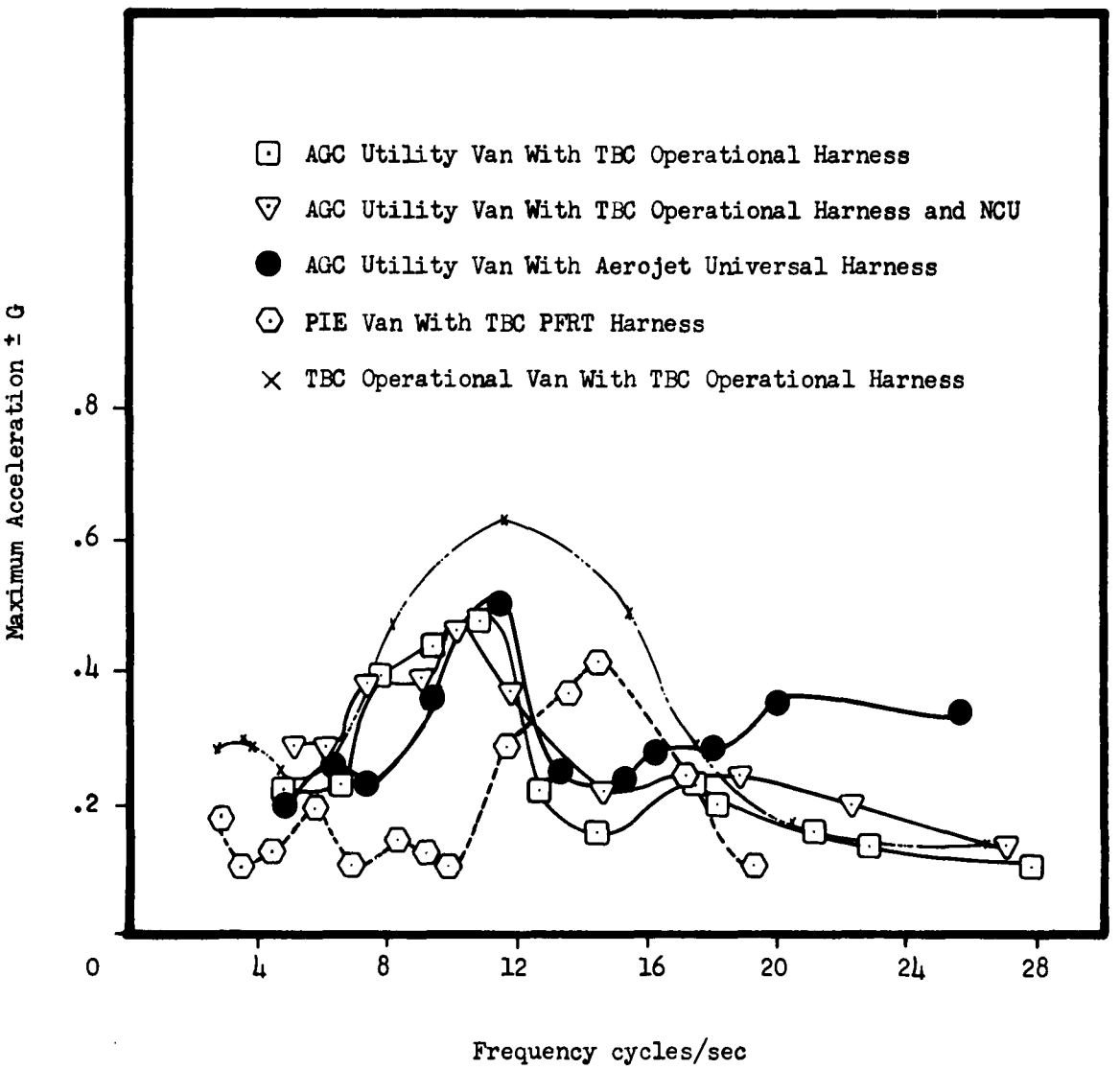
Comparison of Maximum Accelerations at Location G2X for Five Van-Harness Combinations (0.25-in.-High Plank Strips)

Figure 8



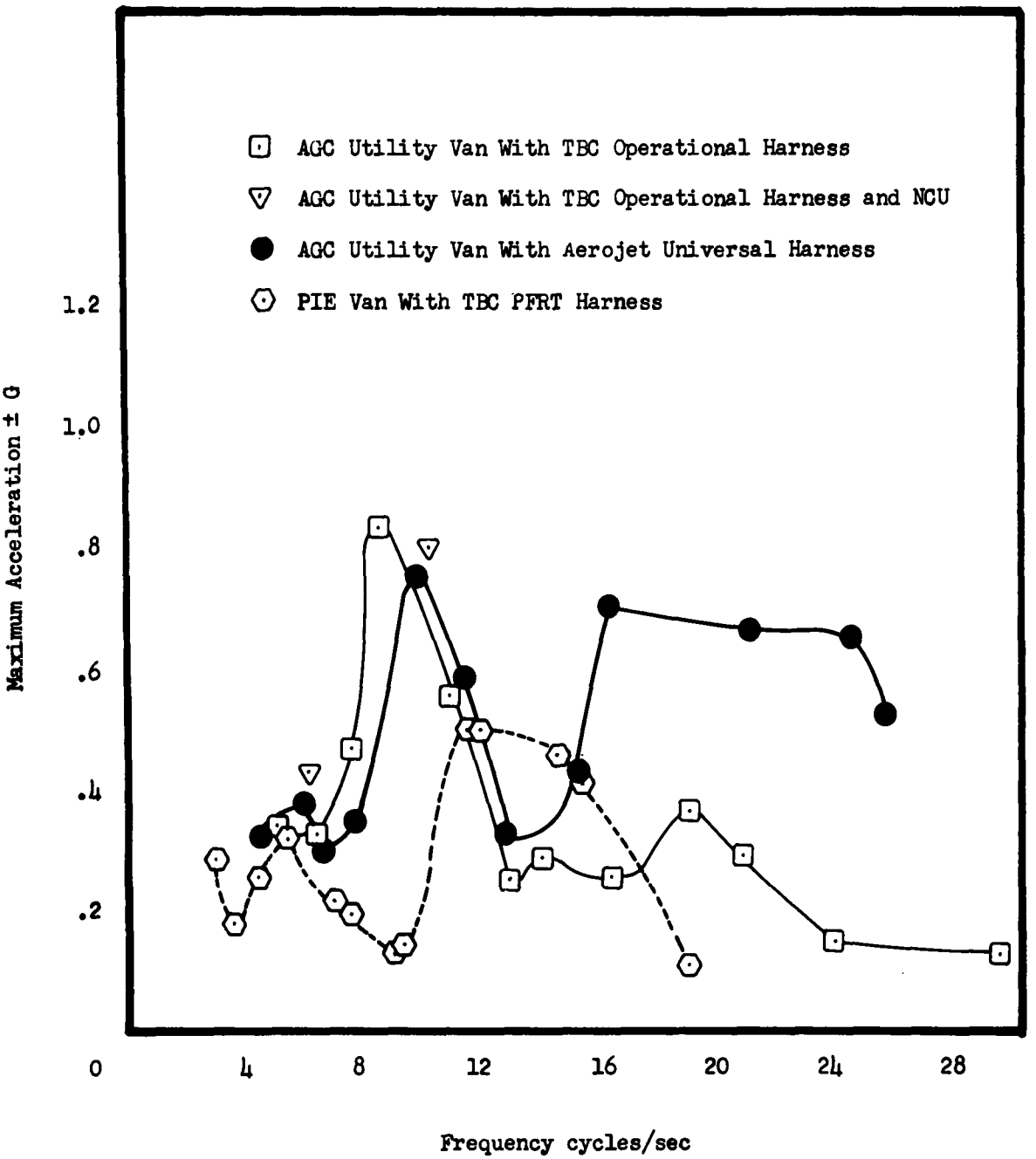
Comparison of Maximum Accelerations at Location G2X for Five Van-Harness Combinations (0.50-in.-High Plank Strips)

Figure 9



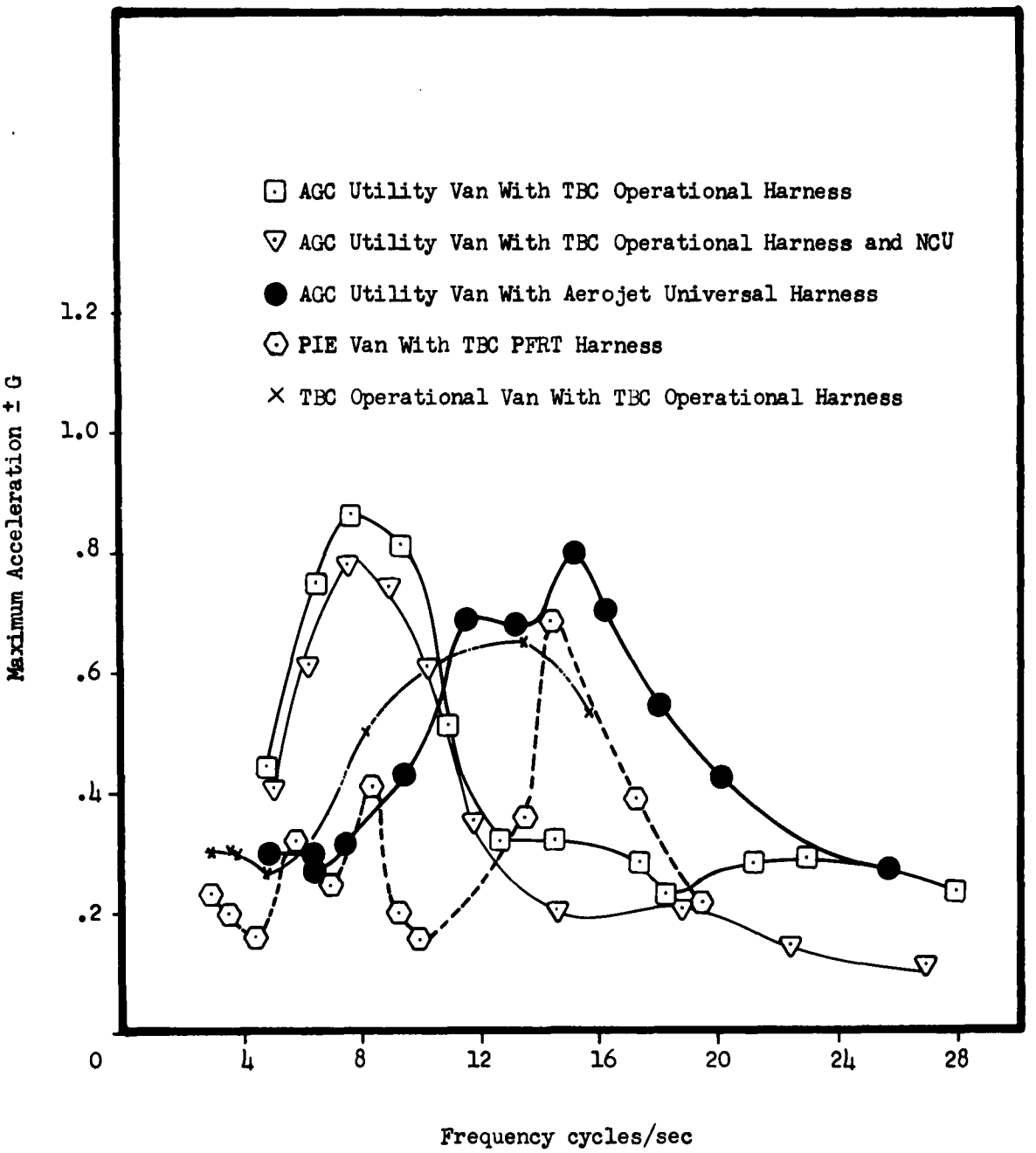
Comparison of Maximum Accelerations at Location G4X for Five Van-Harness Combinations (0.25-in.-High Plank Strips)

Figure 10



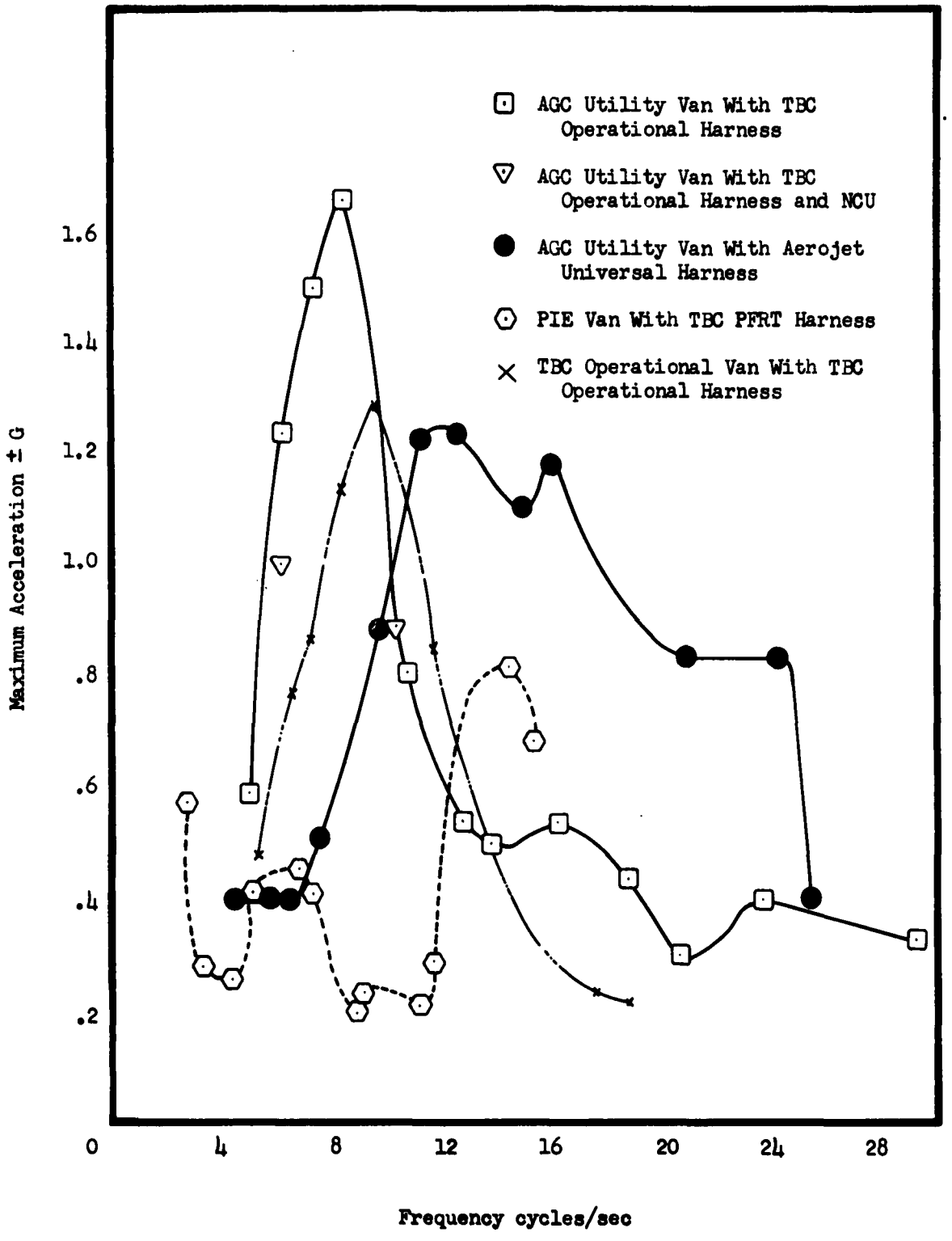
Comparison of Maximum Accelerations at Location G4X for Four Van-Harness Combinations (0.50-in.-High Plank Strips)

Figure 11



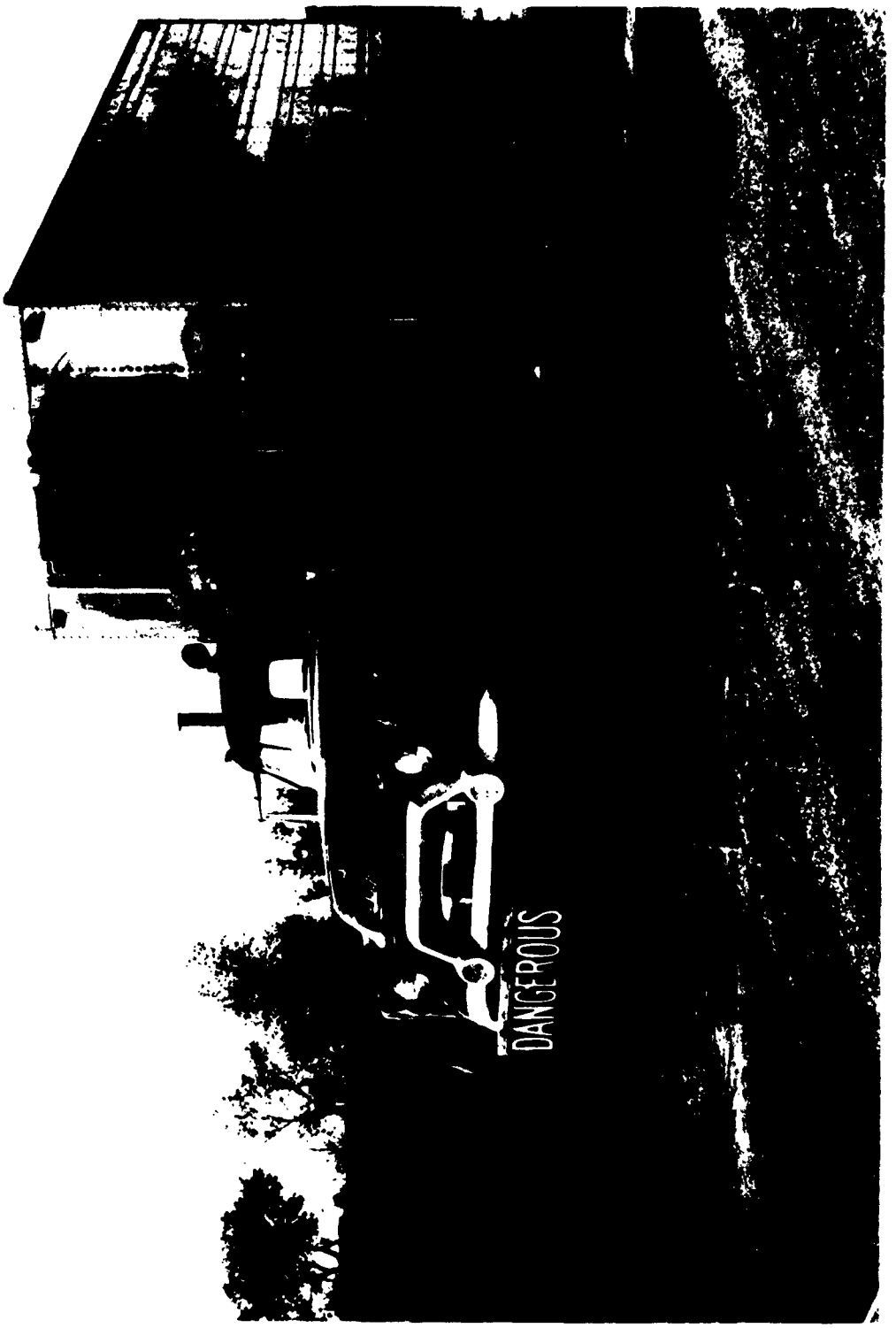
Comparison of Maximum Accelerations at Location G6X for Five Van-Harness Combinations (0.25-in.-High Plank Strips)

Figure 12



Comparison of Maximum Accelerations at Location G6X for Five Van-Harness Combinations (0.50-in.-High Plank Strips)

Figure 13



Aerojet Utility Van

Figure 14

Aerojet-General Corporation
Sacramento, California

RESULTS AND ANALYSIS OF AEROJET-GENERAL UTILITY VAN CERTIFICATION PROGRAM.
by K. H. Staacke. Technical Report
September 1962 12 PP 31 Illus.
AFBSD-TN-BSD-TDR-62-329
Unclassified Report

The Aerojet Utility van, while transporting live Minuteman second-stage motors supported in an Aerojet universal harness, was subjected to a series of plank-strip course and road-condition tests to produce sinusoidal inputs to accelerometer locations on the harness and motor. A comparative analysis of the acceleration-response data recorded during these tests with data obtained in tests of four other van-harness combinations is presented.

UNCLASSIFIED

1. Results and Analysis of Aerojet-General Utility Van Certification Program.

I. Aerojet-General Corporation

II. Air Force Ballistic Systems Division, Air Force Systems Command, USAF

III. Contract No. AF 33(600)-36610

UNCLASSIFIED

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